ANTLIA: AN OUTSKIRT LOCAL GROUP GALAXY

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ABSTRACT.

Deep (I,V-I) and (I,B-I) color-magnitude diagrams (CMDs) of the Antlia dwarf galaxy, based on Science Verification (SV) data collected with the FORS I camera on the ESO Very Large Telescope (VLT) are presented. By adopting the new calibration of the Tip of the Red Giant Branch (TRGB) provided by Salaris & Cassisi (1998) we estimated that the Antlia distance modulus is $(m\text{-}M)_0$=25.98 ±0.10 mag. We suggest an improvement of the classical TRGB method based on infrared H and K magnitudes of TRGB stars. Such a method should overcome the well-known limit of the "classical" TRGB method when dealing with metal-rich stellar populations.

1. The "classical" Tip of the Red Giant Method

Figure 1 shows the (I, V-I) and (I, B-I) CM diagrams of Antlia. As far as the data reduction is concerned, the interested reader is referred to Piersimoni et al. (1999). Data plotted in these CMDs present two key features: a well-defined Red Giant Branch, and a sample of bright blue stars, belonging to a young stellar component. By adopting the new calibration of the Tip of the Red Giant Branch (TRGB) provided by Salaris & Cassisi (1998) we estimated that the Antlia distance modulus is $(m\text{-}M)_0$=25.98 ±0.10 mag, equivalent to D=1.51±0.07 Mpc.

The main aim of this investigation is to present a new calibration of the TRGB method based on NIR magnitudes which can allow us to supply reliable distance determinations for both metal-poor *and* metal-rich stellar populations. In fact empirical evidence suggest not only that the the mean metallicity of LG galaxies range from $[Fe/H] \approx= -2.2 \pm 0.1$ (Ursa Minor) to $[Fe/H] \approx= -0.8 \pm 0.1$ (NGC 205), but also that the average metallicity spread is of the order of 0.5 dex (Mateo 1998). Therefore, the TRGB method cannot be used to supply a homogeneous distance scale in the LG, since both theory and observations support the evidence that I magnitude of the TRGB stars is constant within 0.1 mag, for stellar populations with metal contents [Fe/H] ranging from -2.2 to -0.7 (Lee, Freedman, & Madore 1993; Salaris & Cassisi 1997,1998).

In order to overcome this drawback and to improve the TRGB method in such a way that could be safely used to estimate the distances of stellar systems which include both metal-poor and metal-rich stars, we investigated on theoretical grounds the properties of TRGB stars in the NIR bands. We focused our attention to NIR passbands because they

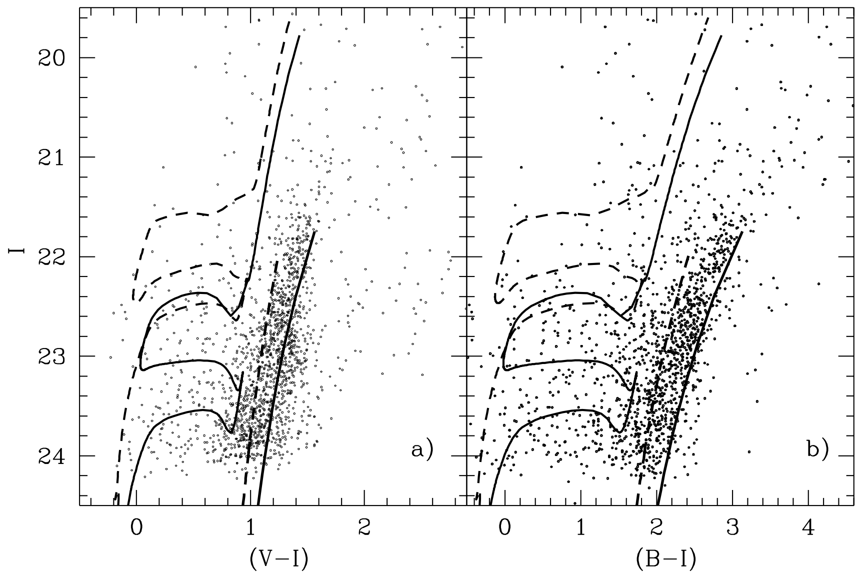

Fig. 1. Antlia CM diagrams: I vs. (V-I) (left) and I vs. (B-I) (right)

present a negligible dependence on interstellar reddening and also a marginal dependence on metallicity.

2. Discussion

The behavior of TRGB magnitude in NIR bands (I,J,H,K) was investigated by adopting the theoretical predictions by Salaris & Cassisi (1997, 1998) which were transformed into the observational plane using the bolometric corrections and the color-temperature relations provided by Wood & Bessel (1994).

Panel (a) of Figure 2 shows the well known behavior of TRGB magnitudes in the I band, i.e. the I magnitude of the tip is not a reliable standard candle for metallicities greater that [Fe/H]=-0.7. Panel (b) of the same figure shows the J band magnitude of TRGB stars. Data plotted in this panel clearly show that the TRGB magnitude in the J band cannot be adopted as a standard candle, since it shows a steady decrease when moving from metal-poor to metal rich structures. The same outcome applies for H and K magnitudes (see panels c and d). A closer inspection, however, reveals that the behavior on this two filters is quite similar and in particular that they present the same slope. This evidence prompted us to estimate the ratio M_H/M_K as a function of

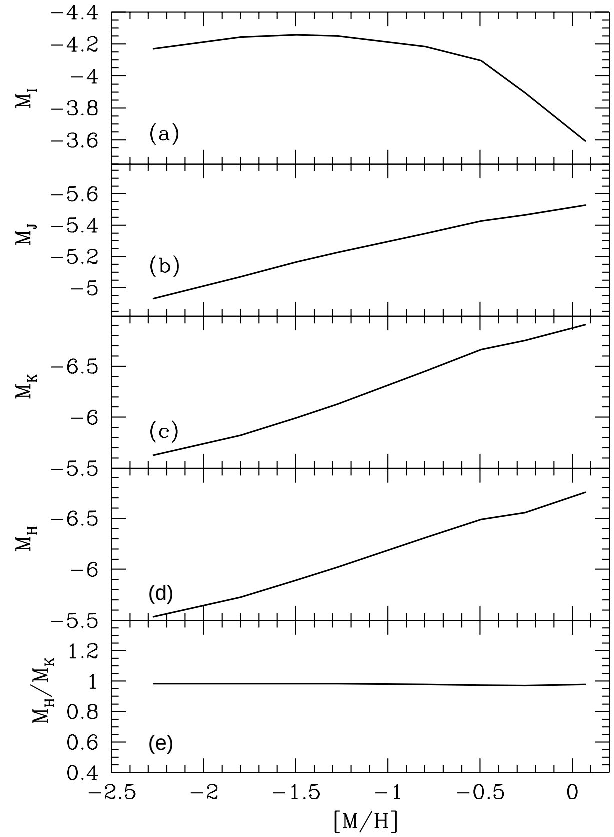

Fig. 2. TRGB magnitude as a function of global metallicity.

metallicity.

Interestingly enough, we found that the ratio M_H/M_K shows a maximum variance of approximately 0.01 mag over the entire metallicity range (see bottom panel) we have taken into account ($-2.5 \leq [M/H] \leq 0.2$). This result suggests that HK ratio can be adopted as a standard candle, since it presents a negligible dependence on metallicity.

3. A possible improvement of the TRGB method

On the basis of the result of the previous section, we can assume that $M_H/M_K \simeq$ const. = a. Then, by accounting for the evidence that the extinction in the H and K bands are quite similar (for $E_{B-V} = 0.1$, we have A_H-$A_K \simeq 0.02$ mag), we obtain

$$m_H - M_H \simeq m_K - M_K.$$

At this point, we can simply derive

$$M_K \simeq (m_H - m_K) \;/\; (a - 1) = (H - K) \;/\; (a - 1).$$

This relation suggests that *dereddened measurements of the TRGB H and K magnitudes, allow us to estimate the distance modulus.* Once this "new" method is supported by empirical evidence it could be adopted to estimate distances of LG galaxies whose stellar populations are older few Gyrs.

Let us briefly mention some drawbacks of the distance indicators currently adopted:

(1) The TRGB cannot be safely applied to all LG galaxies, mainly because of the already quoted "metallicity problem".

(2) Due to the fact that the Horizontal Branch (HB) is intrinsically several magnitude fainter than TRGB, distances based on M_V(HB) can be derived only for nearby stellar systems.

(3) Distances based on "Cepheid PL relations" can be derived only for young stellar systems.

On the other hand, this new approach can be adopted in LG stellar systems characterized by a wide range of ages and metallicities. In fact, modern NIR detectors aboard on VLT (ISAAC) and on NTT (SOFI) allow us to reach H and K magnitudes roughly equal to 19 mag. By assuming a S/N=20, and a seeing of 1.0 arcsec, a limit magnitude K=19 can be reached within time exposures ranging from 650 sec (ISAAC) to 3000 sec (SOFI). It turns out that the TRGB can be measured in galaxies with distance moduli up to 24-25. This means that this approach can be applied for approximately 70% of southern LG galaxies.

The "a" parameter of the previous equation has to be tested and calibrated on NIR data of stellar systems in the LG. Moreover, to test the intrinsic accuracy and reliability of this method we need to collect new NIR data for galactic globular clusters and LG dwarf galaxies whose distance is already well known from other distance indicators.

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